Armed Forces Pest Management Board

TECHNICAL INFORMATION MEMORANDUM NO. 13

ULTRA LOW VOLUME DISPERSAL OF INSECTICIDES BY GROUND EQUIPMENT

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TABLE OF CONTENTS

Report Documentation Page

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FOREWORD

This Technical Information Memorandum is designed to give specific information on DoD policy and current practices for ground application in outdoor situations. Aerial application policies and procedures are not considered, nor are indoor applications. Competency in performance of aerial application requires separate certification by DoD, or an appropriate state agency. Given the sensitivity of the subject, it is imperative that the activity considering outdoor ULV application take time to consider undesired side effects and the opinions of others in the pesticide use debate. As a weapon in the arsenal of integrated pest management, ULV application should be included in the context of reducing the risk of transmission of vector-borne disease through full implementation of as many techniques as are practical given the military, political, or social conditions existing in the area of operations. Protecting the health of service members, family members, and other civilians from excessive exposure to pesticides must be fully incorporated into the treatment plan.

As practices and pest management materiel change, information in this TIM may need to be updated. Your constructive comments are most welcome and will be given full consideration in further revisions of this document. Comments should be sent to Armed Forces Pest Management Board, ATTN: Equipment Committee Ex-Officio, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC 20307-5001.

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1. INTRODUCTION AND PURPOSE

a. Disease vector and nuisance pest control for routine and contingency military operations requires continual modification and updating of techniques and equipment. Coupled with changing pesticide requirements due to resistance and/or environmental considerations, the military utilizes state-of-the-art techniques to ensure protection of its forces. The employment of ultra low volume (ULV) equipment is one example of the methods introduced since 1960 in an effort to improve flying insect control. Primary emphasis is placed on ground control techniques; however, aerial dispersal equipment may be used successfully for vector-borne disease outbreaks where access or terrain curtail the use of ground equipment and vector suppression is immediately required.

b. This memorandum provides information concerning ULV ground dispersal techniques, equipment, maintenance considerations, and methods for required equipment operation evaluation. Equipment and techniques utilized for indoor or aerial ULV dispersal of insecticides are not included.

2. DEFINITION OF ULTRA LOW VOLUME DISPERSAL

a. Ultra low volume dispersal, as defined by the Environmental Protection Agency, is a method of dispensing liquid insecticides at the rate of one half gallon or less per acre (ac). For the control of public health vectors and pests, formulations are dispersed in concentrations of 10-90% at flow rates up to 18 fluid ounces per minute. Technical grade application rates run from 0.001-0.1 gallons (0.006 - 0.06 pounds) per acre. Insecticide is applied as an aerosol consisting of particles ranging in diameter from 0.1 to 50 microns (micrometers = µm); 80% of the particles must have a diameter within the 0.1 to 30 micron range. Droplet parameters within the aerosol range are further specified for each insecticide labeled for ULV dispersal.

b. ULV may also be used for control of agricultural pests. Application rates are usually greater than one pint per acre, and droplets are generally within the 50 to 200µm range.

3. ADVANTAGES OF ULV APPLICATION

a. When compared to high volume methods, the amount of pesticide dispersed to achieve control is greatly reduced. For compounds in current use, the application rate is generally between one and 12 fluid ounces per minute. Methods employed before the introduction of ULV required dispersal rates of diluted pesticides in excess of 60 fluid ounces per minute. With ULV, smaller insecticide reservoirs can be used, significantly reducing weight and cube requirements for a dispersal system.

b. ULV eliminates fog particles (thermal aerosols) that obscure visibility. This is due to the small volume of insecticide released, and the absence of smoke particles produced by thermal fog applicators.

c. The effectiveness of ULV dispersal is equal to or greater than high volume application methods.

d. With the exception of some naled and pyrethroid formulations, diluents, sludge inhibitors or other additives are not required, reducing the cost of the finished formulation. Because storage, mixing and handling requirements for ULV insecticides are minimal, overall operational costs are further reduced.

e. ULV dispersal methods are cost effective. A reduction of 50% in overall operating expenses (time, labor and materials) can be realized when compared to dilute application methods.

f. Proper use of insecticides currently recommended for ULV applications does not constitute a greater hazard to the environment or personnel.

g. The advantages listed above also apply to contingency or emergency operations. Development of lightweight dispersal units using the concentrated pesticide without additives has significantly reduced weight and space requirements for deployment blocks.

4. DISADVANTAGES OF ULV APPLICATION

a. To ensure compliance with label specifications, specialized training for operators is required for calibration, operation and maintenance of equipment.

b. Thorough machine cleaning with solvent is absolutely essential after each operation to maintain equipment in peak operating condition.

c. Collection of insecticide particles on coated microscope slides (or other appropriate methods) is necessary to determine particle size. This should be accomplished at the beginning of each spray season and for every 50-100 hours of operation thereafter. If a machine remains idle for a month or more, recalibration and droplet evaluation are advisable. Specialized equipment and training of personnel are required to properly determine and evaluate droplet production. With instructions provided, the operator can collect droplets from a machine and submit them to a laboratory for analysis. Contact the appropriate pest management professional for information concerning these services. Additional information is provided in Appendix C.

d. Adherence to optimal droplet size, as stated in the label specifications, is essential so that the appropriate amount of insecticide is available in the droplet. Droplets too large fall to the ground quickly, reducing insect exposure time and increasing potential hazards to the environment or personnel. Furthermore, droplets exceeding sizes stated in label specifications are capable of causing damage to automobile finishes or other painted surfaces. On the other hand, smaller droplets are more susceptible to drift and aerodynamics around the target and will therefore fail to impinge.

5. DISPERSAL METHODS AND EQUIPMENT

a. Basic Considerations. Effectiveness of ULV ground dispersal for adult flying insect control is dependent on the same factors involved in any outdoor aerosoling program: meteorological conditions, topography, vegetation density, proper equipment operation, correct vehicle speed, insecticide flow rate, activity of target population and insecticide effectiveness. Droplet size, droplet distribution and application rate have added significance because of the very small volume of insecticide applied to an area to achieve control.

b. Equipment. ULV ground equipment, whether produced for commercial or military use, must meet certain requirements. Components coming in contact with the insecticide merit special attention; these are: tubing carrying the insecticide from the reservoir to the atomizing head, interior solenoid valve mechanisms, pump assemblies, and exterior portions of the dispersal unit subject to liquid contamination. Equipment intended for use over rough terrain should be designed to withstand hard usage without breakdown. Electronic components should be heavy duty to withstand the effects of heat, solvents, and vibration. A review of ULV ground dispersal equipment indicates that many

manufacturers use common components. Therefore, several generalizations concerning design (e.g. FMI pumps, Roots blowers) and operation may be made.

c. Methods of Generating ULV Droplets.

(1) **Air-liquid mixing chambers (turbulence chamber) (mechanical methods).** Insecticide and air are mixed together under pressure in a chamber to produce atomization. The mixture is delivered to the outside air through single or multiple nozzles. Pressure generated by a blower or compressor may deliver air at high volume and low pressure, or high pressure and low volume, depending on equipment design. Dispersal units are usually powered with gasoline engines. These devices have the greatest versatility in the selection of air and liquid pressures or flow rates to facilitate liquid breakup and control particle size.

(2) **Thermofogger (thermal methods).** Two basic types of thermofoggers are manufactured: rotating disk and heat chamber. In the rotating disk type, insecticide is drawn between rotating disks, heated and shunted into the exhaust system. The insecticide fuel oil mixture is vaporized at a relatively high temperature (generally $\geq 250^{o}$ F) in the exhaust port and forced into a relatively low atmospheric temperature where condensation (= fog) occurs. The heat chamber type also disperses an insecticide fuel oil mixture. However, a standard insecticide pump is used to shunt the material into a "heating chamber" where vaporization occurs. A Roots blower is used to force the vaporized material into the adjacent atmosphere, which drives the condensation.

(3) **Rotating sleeves (mechanical).** Insecticide under pump pressure is introduced into a rotating porous cylindrical sleeve, forcing the liquid through minute openings to produce atomization. Droplet size may be controlled by the porosity of the sleeve and by varying the insecticide pressure and flow rate. Breakup of the liquid may be further enhanced by air delivered from a fan producing a shearing action on the droplets. These units are usually electrically powered by 12-volt storage battery systems; sleeves and pumps are driven by electric motors.

(4) **Rotating discs (mechanical).** Insecticide breakup is accomplished by introducing the liquid by gravity or pressure onto a motor-driven, cylindrically shaped disc rotated at high speed. The insecticide impinging on the disc is propelled outward to provide initial breakup. Shear produced by a motor-operated fan produces atomization. These devices may be hand-held or portable and are powered by batteries.

(5) There are several brands/models available for each method described above. Generally, each equipment company develops its own proprietary nozzle design to ensure the company’s uniqueness. There are many references comparing proprietary nozzles. The label requirement for droplet spectra, however, is what determines whether a nozzle meets standards.

d. The Influence of Droplet Size and Dispersal Rate upon Practical ULV Control Operations.

(1) It is generally accepted by the mosquito control industry that optimum droplet size for mosquito control is in the range of 5-25 microns in diameter for Fyfanon™ . Insecticidal efficiency decreases rapidly for sizes smaller than 5 and larger than 25 microns, but little difference in efficiency is noted for sizes from about 7 to 22 microns. Generating droplets larger than this is wasteful or at best inefficient for ground dispersal application. Label specifications for ULV insecticides other than Fyfanon™ are generally in agreement with the above statements.

(2) Although mosquito populations are usually managed by ULV insecticide application following the

standards described above, exceptions have been noted. For example, it has been shown that the same application rate of pesticide may not work for all species of mosquitoes. Application error, subject to ambient winds, may provide some of this variability because different species occur in different habitats - and different habitats affect aerosol dynamics in many ways. There is still much research to be done in this area. Another source of variability in treatment effectiveness is target species biology, which is species specific and genetically influenced. Body weight, flight habits, aerosol cloud dynamics, and ultraviolet light are all variables in this complex equation that determines final insecticide efficacy. Obviously, alteration of application rates may be necessary to compensate for some or all of these factors.

(3) The type of terrain and vegetation will greatly influence the requirements for droplet size and the ultimate effectiveness of an application. In open terrain with relatively sparse vegetation, greater effective swaths can be obtained. As vegetation density increases, the opposite holds true. This ‘insecticide/vegetation penetration’ factor must be considered for each environment.

(4) Wind speed has a profound influence on particle distribution and impingement. For most operations, wind speeds from 1 to 10 miles per hour (mph) will produce the best results. However, some experimental data indicate that wind speeds in excess of 10 mph may markedly increase the effective swath width where vegetative penetration is desired. **Read the label.**

6. EQUIPMENT FOR MILITARY USE

a. General Considerations. Since the initial acceptance of the ULV method for insect control, design and construction of commercial and military dispersal devices have been in states of constant change. The first generation of ULV dispersal units required application methods based on rather strict insecticide temperature conditions and vehicle speeds. Although it is beyond the scope of this memorandum to describe the history of ULV equipment development, it should be noted that the military has been instrumental in promoting significant improvements. Current military specifications (1985) reflect these developments for large engine-operated and hand-held equipment. Recently, commercial competition and field requirements generated by civilian and military agencies have stimulated innovations in equipment design that have simplified control operations and allowed greater latitude in application methods independent of speed and temperature requirements. Consult Technical Information Memorandum 19, Catalog of DoD Pest Management Materiel, Other Than Pesticides (to be published January 2000) for further information and images of the below listed items.

b. Equipment for Contingency Operations. Adulticiding equipment for use by military units in contingency or combat operations requires unique features. Equipment must be simple to operate and maintain, lightweight and portable, generate low noise levels, utilize a variety of pesticide formulations, and atomize effectively. Battery-powered units often fulfill these requirements and have been accepted by the mosquito control community in the last decade. Both hand-held and truck-mounted units are available.

c. Standard Stock ULV Generators.

(1) Dispensers procured for standard stock consumption are supplied as complete units with operating manuals and are ready for use. Spare parts are not provided but may be procured by military or open

purchase procedures. Operating and maintenance procedures should be thoroughly studied before attempting operations. Units dependent on liquid temperature should be initially calibrated for the range of their expected use in five-degree increments, usually 60 to 100^{o}F. To ensure maximum effectiveness and minimize paint damage, droplet samples should be taken and validated prior to machine use.

(2) Gasoline engine powered equipment. Military specification MIL-A-52940B applies to dispersal units procured after October 1984. Equipment procured before this date and supplied under standard military procedures may be one of the following:

(a) **Aerosol Generator, Pesticide, Skid Mounted, Whitmire Micro-Gen G9HD™ (NSN 3740-01-083-3570).** Heavy duty unit employing a positive displacement pump system. A module mounted near the operator provides controls to adjust flow monitored through a direct reading digital indicator system. The module also provides engine and pump controls for remote operation. 10.5 HP, Flow rate: 1 - 20 oz/min, Wt: 320 lbs.

(b) **Fog Generator, Skid Mounted, Leco Model 7000-011 (NSN 3740-00-375-9154).** Positive displacement pump with 6 psi. Machine no longer manufactured. It has been included to accommodate component part replacement.

12.5 HP, Wt: 456 lbs.

(c) **Aerosol Generator, Pesticide, Skid Mounted, Curtis Dyna Model 2740 Series ll. (NSN 3740-01-141-2557).** This heavy-duty unit employs a positive displacement pump. Operation can be controlled from the truck cab with a remote device that provides flow control, flushing control, and a fault indicator.

(d) **Fog Generator, Insecticidal, Curtis Dyna MDL 2952. MIL-A-5294C, Type ll. (NSN 3740-01-206-9635).**

(e) **Sprayer Pesticide, Skid Mounted, Beecomist Systems™ Promist (15MP) (NSN 3740-01-206-9635).** 12V DC powered. Atomization is accomplished by a motor-driven porous polyethylene sleeve and blower combination. Insecticide is supplied to the sleeve by a motor-driven constant volume pump delivering a maximum of 6 fluid ounces per minute. A remote module controls all dispersal and flow system cleaning functions through a series of switches. Vehicle wiring kit (PN A4006), Wt: 95 lbs.

(f) **AGULVE, Sprayer, Pesticide, Skid Mounted, Beecomist Model Pro Mist 15MP with aluminum frame (NSN 3740-01-445-8380).** 12 V DC, Wt: 95 lbs, Vehicle wiring kit (PNA4006).

(g) **Aerosol Generator, Pesticide, Skid Mounted, MIL-A52940C, Type l (NSN 3740-01-062-8043).** Flow rate: 1.5-18 oz/min. Wt: 400 lbs, 100 psi.

d. Hand-held Standard Stocked ULV Generators for Contingency Operations. Several units have been accepted for use by the Services for contingency operations and are currently listed on some or all of the military services authorized materials allowance list. These are:

(1) **Sprayer Manually Carried, DC powered (rechargeable battery), Ulvafan™, Dram Model MK2 (NSN 3740-01-206-9636).** Flow rate: 60 ml/min at 3 PSIG. Wt: 3.25 lbs. This electric powered hand-held device is configured to disperse aerosols and mists. It is powered by a rechargeable 12-volt Gel Cell™ shoulder-carried battery pack. A spinning disc dispersal head and fan combination provide pesticide atomization. Flow rate is controlled by interchangeable gravity feed nozzles.

(2) **Fog Generator, Manually Carried, Thermal Fog. Curtis Dyna Model 2610 Golden Eagle™ (NSN 3740-00-818-6648).** Flow rate: 5 GPH at 6 psi. Wt: 19 lbs.

(3) **Fogger, Hand Held, Gasoline Engine Driven. London Fog Eliminator™ (NSN 3740-01-456-26250).** Flow rate: 5-6 GPH, Wt: 24 lbs.

(4) **Fogger, Hand Held, Gasoline Engine Driven. London Fog Colt™ (NSN 3740-01-456-2622).** Flow rate: 0-4 oz/min, Wt: 19 lbs.

(5) **Fogger, Hand Held, Gasoline Engine Driven. Clarke P-1™ (NSN 3740-01-456-2623).** Flow rate: 0-4 oz/min, Wt: 17 lbs.

e. Backpack Dispersal Units. Most of the currently manufactured backpacks can disperse liquid, dust and/or granular formulations with accessory attachments. Generally, liquid dispersal rates and droplet sizes exceed those required for ULV insect control. However, some backpacks do meet ULV criteria. Historically, these devices provide limited flying insect control, because of small capacities, and are more effective in residual treatment. The Kiortiz DM-9, readily available through supply channels, was the DoD standard for several decades. Recently, however, production was stopped and the device has been replaced by the following model.

Sprayer-Duster, Pesticide, Backpack, STIHL® Model SR400 (NSN 3740-01-463-0147). ULV nozzle included - discharges mist 38 ft vertical/40 ft horizontal, Wt: 24 lbs.

7. APPLICATION OF ULV INSECTICIDES

a. General Considerations.

(1) Although a number of insecticides are labeled for outdoor pesticide dispersal, relatively few are needed for military use. Currently available standard stock insecticides will satisfy most requirements. Occasionally non-standard pesticides may be needed to overcome a resistance problem, meet specific legal requirements, or satisfy environmental constraints. Also, where the odor of the pesticide is offensive and cannot be tolerated, substitution may be desirable.

(2) Operational application factors must also be considered, and all are equally important. These are: (1) application rate required, (2) swath width, (3) flow rate and vehicle speed, and (4) particle size produced by the machine.

b. Standard Stock Pesticides for ULV Dispersal.

(1) **Fyfanon™ (NSN 640-00-655-9222, 57%), (6840-00-685-5437, 57%), (6840-00-685-5438, 57%), (6840-00-926-1481, 95%) and (6840-00-169-1842, 95%).** This is the most commonly used organophosphorus compound in the United States for ULV ground dispersal. Advantages include demonstrated effectiveness against many pest and vector species and its relatively low mammalian toxicity. However, when applied in droplets much larger than those specified in the label, this compound has the ability to damage acrylic-based automobile paints. Machine adjustment must therefore be exact, and application rates followed carefully. The original label specifications called for a maximum application rate of 0.04 pound actual per acre (0.5 fl oz/acre). A label revision in 1972 allowed the

maximum application rate to be increased to approximately 0.057 lbs./acre (0.716 fl oz/acre). This rate corresponds to a vehicle speed of 5 mph, swath width of 300 ft and a flow rate of 1-2.1 fl oz/min., or a vehicle speed of 10 mph and a flow rate of 2.0-4.3 fl oz/min.

(2) **Naled (Dibrom™) (NSN 6840-01-270-9765, 85%).** This compound may be

applied at the rate of 6-12 fl oz/min of Dibrom 14™ concentrate diluted as a 0.5 - 4.5 gallon mixture in either heavy aromatic naphtha (HAN) or vegetable oil. This corresponds to a technical grade application rate of 0.01-0.02 pound per acre. This is the application rate for a vehicle speed of 10 mph, and flow rates should be adjusted accordingly for higher or lower vehicle speeds. In 1997 an EC version, Trumpet™ , became available.

(3) **Chlorpyrifos (Dursban™) (NSN 6840-01-122-2652, 42%, EC 4E), (6840-00-402-5411, 42%, EC4E), (6840-01-203-6161, 19.36%, Mosquitomist, 1.5 ULV).** This compound may be applied at the rate of 0.67-1.3 fluid ounces per minute for the undiluted 6 pound per gallon concentrate. (The basic producer has decided to discontinue this concentration and it is expected that chlorpyrifos 1.5 pounds per gallon ULV concentrates will be substituted). The 1.5 pounds per gallon ULV concentrates should be applied undiluted at a flow rate of 2.7-5.3 fluid ounces per minute and an average vehicle speed of 10 mph. These flow rates correspond to a dosage equivalent of 0.005-0.01 pound per acre for either concentration of chlorpyrifos based on an effective swath width of 300 feet. Flow rates should be reduced accordingly if a 5 mph speed is used.

(4) **Pyrethrins, 3% pyrethrins with synergists (ULV fog concentrate) (NSN**

6840-01-104-0780).

(5) **Resmethrin (Scourge™) with SBP-1382® / piperonyl butoxide 4% + 12%**

MF (ready to use) (NSN 6840-01-359-8533). At 5 mph with a 300 ft swath width the low flow rate is 0.007 lb. ai/ac. At 10 mph with a 300 ft swath width the rate is 0.021 lb. ai/ac.

c. Non-standard Pesticides for ULV Dispersal.

1. Baytex™ Liquid Concentrate.
2. Several Pyrethroid Compounds with Synergists are available.

d. Computation of Dosage Rates for ULV Insecticides.

(1) General Considerations. Any computation of deposition is based on the definition of the area to be treated, and therefore the depth of treatment, or swath, must be established to enable computation of the dosage rate. Dosage is expressed in either fluid ounces or pounds of technical concentrate (actual) per acre. In reality what is being treated is a volume of air above the surface of the earth, called the "insect zone."

(2) Swath Width. Perhaps no other single factor in the computation of dosage rate receives so much discussion as the meaning of the term "swath" or "effective swath width." Many arbitrary definitions have been given to this term. The recommendations of the manufacturer or governmental research activities will be acceptable as guidelines. In practice, the operator is governed by the actual area he is required to treat. He may not be able to apply insecticide in the exact manner recommended due to the

physical layout or geography of the area. As long as the insecticide is dispersed evenly at recommended rates in more or less equal swaths across the area to be treated, the control procedure will be effective. According to published information, the swath width determined for the application of Fyfanon™ ULV and other insecticides is 300 ft, which is adequate for all but the most densely vegetated areas. Historically, this 300 ft interval came from the center of one road to the center of the next road, demarcating a city block. In early tests, treatment of that area with insecticide resulted in 80% mosquito mortality and was accepted as the standard. In open terrain, good control has been obtained at swaths of 2000 feet or more. Effective swath width is the distance at which "effective" control is obtained. Generally, an effective swath width is determined by experimentation. It is accomplished by one of two methods: direct evaluation of kill of exposed caged insects, or reduction in landing rate on humans where a natural infestation occurs. An arbitrary definition of the term "effective" is "85%" control. Swath width is generally included on the insecticide label. If not, then tests should be conducted to determine the distance at which 85% control is achieved. These tests are highly variable in nature, requiring sufficient replications to achieve an acceptable statistical level, and may require more time than the average mosquito control district or military operations spray team may have. The Command Pest Management Consultant/Entomologist and distributor/formulator should be able to address questions concerning swath width. Once the swath width has been established and a firm recommendation has been made by a

company or agency, the operator should make every effort to adhere to the recommendation for swath spacing, vehicle speed, and output to accomplish effective control.

(3) Determination of Application Rate.

(a) General Considerations. Each insecticide has different physical and chemical properties, and biological effectiveness. Therefore, different dosage rates must be established for specific control situations or species involved. The application rate, or delivered volume per unit of time, will depend on the weight of the concentrated insecticide, the speed of the vehicle, and the established effective swath. Using these figures, simple arithmetical calculations can be made to determine deposit rates per acre for effective control. An example for Fyfanon™ will be given here. The calculation method is essentially the same for any other insecticide or formulation.

(b) Mathematical Calculations.

Determination of acreage covered. It has been established that the effective swath for ULV Fyfanon™ applications is 300 ft, and practical vehicle speeds have usually been set at either 5 or 10 mph. Therefore:

Vehicle speed (mph) x 5280 (ft. in 1 mile) x swath in feet / 43560 (sq. ft in 1 acre) = acres covered per hour

For a 5 mph rate: 5 x 5280 x 300/43560 = 181.8 acres/hour.

For a 10 mph rate, this figure would be doubled, or 363.6 acres/hour.

The established flow rate for 5 mph is a maximum of 2.1 fluid ounces per minute or for one hour is 60 x 2.1 = 126 fluid ounces per hour. Therefore 126 / 181.8 = 0.6931 fluid oz/ac.

The stated weight of technical Fyfanon™ per gallon is 10.25 pounds per gallon. One fl oz will weigh: 10.25 / 128 (fl oz in gal) = 0.08 pounds per fluid ounce. Therefore, the deposit rate per acre is 0.08 x

0.6931 or 0.055 lbs/ac deposit of technical (actual) Fyfanon™ . For 10 mph, and a maximum flow rate of 4.3 fl oz/min, the flow rate is:

(60 x 4.3)/363.6 = 0.71 fluid ounces per acre, or a deposit of 0.08 X 0.71 = 0.0568 pounds per acre deposit of technical Fyfanon™ .

Simpler procedures can be used to determine the same figures as above. An effective, and essentially as precise method of determining the acreage covered per minute is:

Speed (mph) x swath (ft.) / 500 = acres covered per minute

For example, a speed of 5 mph with a 300 foot swath gives

5 x 300 / 500 = 3 acres per minute. For a maximum flow rate of 2.1 fl oz/min, the deposit rate per acre is 2.1 / 3 = 0.7 fl oz/ac, or a deposit of 0.08 x 0.7 = 0.056 lbs/ac deposit of technical Fyfanon™ . The deposit rate for a 10 mph speed is 10 x 300 = 6 acres per minute when the flow rate is doubled, and deposit rate is the same 0.056 pounds per acre.

(4) Calibration Techniques.

(a) Method for machines with in-line flow meters and temperature gauges.

The method of calibrating the flow rate of ULV equipment is relatively simple, requiring a stop watch and a graduated cylinder marked in tenths of an ounce or in cubic centimeters (milliliters). First, the machine is placed in operation; then, adjust the engine speed to establish proper insecticide tank pressure, and fill the insecticide lines. This may require letting some ‘run out’ in order to fill the lines. Set the flow meter to an arbitrary setting (about mid scale). Remove the discharge tube from the dispersal head, and hold it at the same level. Activate the solenoid valve to start discharge. The insecticide is allowed to flow for one minute, and the measurement is made directly in fluid ounces or milliliters per minute. For example, if the machine is operated for one minute, and the total amount of liquid discharged in this time is 128 ml, the flow rate is 4.3 fl oz of Fyfanon™ per minute.

128 ml/min / 29.57 ml in 1 fl oz = 4.3 fl oz / min

This is the maximum discharge rate allowed at 10 mph. If the total flow is higher or lower than this rate at the existing temperature, an adjustment of the needle valve must be made to establish proper flow. Be sure to record the temperature at this setting, since the flow rate must be readjusted for any positive or negative change in temperature of 5 degrees or more.

If a machine is calibrated at a stated insecticide temperature, the machine should be used for operations under the same or nearly identical conditions, or the flow rate may differ greatly from that previously calibrated. Too little flow or output means poor control; too much output means waste, a possibility of paint damage or adverse effects on the environment. Calibration of a machine should be made periodically, usually after 25 hours of operation, or any time when major maintenance is performed. Furthermore, if a change in insecticides is made, recalibration must be performed. A calibrated graph should be plotted for high and low flow rates at temperatures between 60-100^{o} F. For any major change in insecticides or operating conditions, a slide sample of droplets should be obtained.

(b) Method for Constant Volume Output Machines. None of the machines produced for commercial or

military use have identical systems for control of liquid output. Follow the instructions provided with the equipment to determine flow rate. Although direct readout of flow may be indicated, its accuracy should be checked by the method in (a) above at some ambient temperature within the expected machine operating range.

(c) Method for Gravity Flow Machines. Hand-held equipment may employ gravity feed systems using interchangeable orifices for establishing flow rate. For public health ULV operations, usually the smallest orifice provided will produce the desired flow. A large beaker may be used to collect the liquid for transfer to a graduated cylinder for accurate measurement. With the smaller hand-held machines, calibration may offer more technical difficulty. Calibration in these cases may require that someone time an application as the operator sprays over a certain area.

8. DROPLET SIZE FOR ULV APPLICATIONS

a. General Considerations. Before the development of ULV techniques, a general knowledge of the characteristics and droplet size of a dispersed insecticide was all that was usually necessary to understand control principles. Because ULV methods employ only a small amount of insecticide, knowledge of the characteristics of droplets and their ultimate destination and deposition becomes of paramount importance if ULV dispersal is to be accomplished effectively and safely. This is especially important when application rates of one fluid ounce per minute are used.

b. Droplet Size.Collection of insecticide particles on coated microscope slides is necessary to determine particle size. This should be accomplished at the beginning of each spray season and for every 50-100 hours of operation thereafter. If a machine remains idle for a month or more, recalibration and droplet evaluation are advisable. Specialized equipment and training of personnel are required to properly determine and evaluate droplet production. With instructions provided, the operator can collect droplets from a machine and submit them to a laboratory for analysis. Contact the appropriate pest management professional for information concerning these services. Additional information is provided in Appendix C.

c. Distribution of Droplets for ULV Dispersal.

(1) Understanding label specifications and droplet distribution in an aerosol cloud requires knowledge of the term mass (or volume) median diameter (MMD or VMD) expressed in microns. This is the closest description that can be employed to characterize a wide distribution of droplet sizes. There are several methods currently used to determine droplet size. Three popular for field use in mosquito control are: PCDC-3 (KLD Labs, Inc., Huntington Station, NY), Teflon® slides, and silicone slides. The PCDC-3 is a ‘hot-wire’ probe that is inserted into an aerosol cloud, and conductance change is measured when droplet impingement occurs. This measurement is converted to an MMD and printed out automatically. The distance at which the probe must be held is dependent on the ‘airblast’ from the sprayer and will differ from machine to machine. However, the probe must be held where the airblast is 3-7 m^3/sec. Teflon® and silicone slides are used in the following manner to characterize droplet size distribution and can be employed to characterize a wide distribution of droplet sizes. The total volume of a droplet sample collected on a coated microscope slide (200 droplets on some labels) is calculated and divided into two equal volumes. The division line is the VMD, which means that half of the volume will have droplets smaller than the VMD number, and half the volume will have droplets larger than the VMD number. The measurement is expressed in microns. Some current ULV labels still use the term MMD, although most recent literature uses the term VMD. These terms are synonymous and interchangeable as

they relate to the very small droplet sizes in ULV applications. Droplet sizes should show a reasonable distribution around the VMD, and an aerosol for ULV dispersal will generally fall between 5 and 25 microns. A large number of very small or large droplets outside the 5-25 micron range indicate incorrect atomization. Usually some adjustment to the flow rate or other machine operating characteristics will be required to establish the correct range. If a large number of droplets, five microns or less, are produced and they constitute a small percentage (less than 10%) of the volume (mass), the remaining droplets will normally produce effective control. However, the final guidance, and the law, is the insecticide label. Labels vary in their requirement of VMD and selected ones are listed below.

(2) When a slide sample is analyzed by a qualified agency, other factors, such as the distribution of droplets by number (frequency or numerical median diameter - FMD), percentage of volume in each droplet size category, and other factors related to label specifications, will be considered. For the equipment operator, the knowledge of VMD size, percentage of volume within a certain range, and the largest droplets generated by the machine will usually be sufficient to tell him if his equipment is operating properly.

(3) There are certain standards set by federal and state agencies and chemical companies for the performance of a machine and a given pesticide. These standards, as part of the label specifications, must be met so that effective control can be achieved and hazards to personnel and property minimized.

d. Requirements for Droplet Size: Label Specifications.

(1) Portions of label specifications for the commonly used standard stock pesticides are quoted below as general guidelines. Before attempting operations or droplet assessment, read the complete label to ensure best results.

(2) Label Specifications for Fyfanon™ ULV

(a) Droplets must not be less than 5 microns in size, as the smaller droplets do not impinge readily on adult mosquitoes.

(b) Droplets should not exceed 32 microns in size. Up to 3% can exceed 32 microns provided the VMD does not exceed 17 microns and no droplets exceed a maximum of 48 microns.

(c) More than one-half of the total spray mass must consist of droplets in the 6-18 micron range.

(d) A minimum of two-thirds, preferably four-fifths, of the total spray mass must consist of droplets not exceeding 24 microns in diameter.

(e) The mass median diameter should not exceed 17 microns.

(f) The average diameter of the droplets should not exceed 12 microns.

(g) When Fyfanon™ droplets are collected on silicone coated slides, the spread factor, if not actually computed for an individual slide, is 0.5 (see Section 9, below).

(h) Sampling distance should be 25 feet from the point of discharge.

(i) Silicone- or Teflon®-coated slides may be used for sampling.

(3) Label Specifications for Dursban™ Formulations.

(a) Droplets should be produced in the range of 5 - 30 microns.

(b) The volume median diameter produced should be 10 - 15 microns.

(c) Sampling distance should be six feet from the point of discharge.

(d) Silicone coated slides may be used but Teflon® is preferable.

(4) Label Specifications for Dibrom 14™.

(a) Maximum effect is produced by particles that range in size from 11-20 microns.

(b) Volume median diameter of the droplets produced should not exceed 15 microns and no droplet should be larger than 50 microns.

(c) Sampling distance should be 3-6 feet from the point of discharge.

(d) Silicone coated slides may be used but Teflon® is preferable.

(5) Resmethrin (Scourge™) .

(a) For use in nonthermal backpacks when the material is diluted with oil, the VMD should be 18-50 microns. The label should be consulted for dilution and application rates.

(b) For truck-mounted nonthermal ULV, adjust equipment to deliver fog particles of 8-20 microns. The label should be consulted for dilution and application rates.

It should be noted that these figures are for ground ULV applications, NOT AERIAL. Aerial VMD requirements for each chemical are significantly different.

9. MEASUREMENT OF DROPLETS FOR ANALYSIS OF ULV PERFORMANCE

a. General Considerations. As outlined above, critical considerations must be met for droplet size in ULV applications, and the methods of analysis are equally as important as the insecticides and equipment employed to disperse them. Techniques such as automatic particle size counters, electronic scanning photography, lasers, chemically treated paper, "roto-rods", Cascade Impactor, magnesium oxide slides, settling chambers, carbon black and several types of gels may be used to determine droplet size. Several methods measure too coarsely or may fall into the realm of research techniques. Each method measures an optimum droplet size range for which it is selective (Rathburn, 1970). Magnesium oxide-coated slides are accepted as being the method of choice for water-based droplets (Rathburn, 1970). This method requires careful preparation techniques in preparing the slides.

(1) For practical routine work, microscopic techniques are adequate to perform droplet analysis. The only equipment required is a good quality compound microscope, using an eyepiece micrometer for measurement of droplet diameters. Accurate calibration of the microscope is essential and can be easily

accomplished by an experienced laboratory worker. See Appendix C for details.

(2) Silicone-coated slides are commonly used when determining droplet size with a compound microscope. Standard, flat microscope slides are used, coated with a 10% solution of "Dri-Film™" silicone compound, in a diluent of acetone or toluene. Slides can be lettered or numbered with a diamond point stylus for identification. The slide is dipped in the solution, allowed to dry, and polished with clean lint-free tissue. The slides can be retained indefinitely in this state until ready for use.

(3) Teflon®-coated microscope slides are also recommended for use in collecting insecticide droplets. They are especially valuable in collecting droplets where oil is used as diluent, such as Fyfanon™ , chlorpyrifos, naled and some pyrethroid compounds. Silicone coatings are miscible with these formulations and will produce erroneous results. (See Appendix F, Sources of Supply).

b. Routine Field Collection Procedure for Insecticide Aerosol Droplets. Samples of droplets may be collected by waving a coated slide through the aerosol cloud at the required label distance. For each pesticide labeled for ULV, the collection procedure is described and the sampling distance is specified. The general details of this procedure are described in Appendix C, below. A list of materials and potential sources of supplies to make a ULV droplet analysis kit are at Appendix D, below.

c. Methods of Particle Measurement.

(1) Excellent reviews of particle measurement have been published by A.H. Yeomans (USDA Publication ET-267: 1949), Matthews (1992) and Rathburn (1970) and are included in Appendix A, below. These publications remain timely and helpful in describing procedures to permit proper analysis of ULV droplets. Additional information may be obtained from references in their bibliographies. Specific guidelines for droplet measurement can also be obtained from the John A. Mulrennan, Sr. Research Laboratory, Florida A & M University, Panama City, FL 32405.

(2) A magnification of 100X is recommended when performing droplet measurements, although many workers use a magnification of 400X. This practice is satisfactory for uncovered slides, but difficult to achieve with covered slides prepared as described in Appendix A.

(3) For field or contingency operations, a 100X magnifier may be used as an alternative to a more expensive, heavy and often difficult to obtain compound microscope. Using this device and a fixed spread factor, field measurement and assessment of droplet spectra can be satisfactorily performed with minimal measurement error.

d. Statistical Evaluation of Recovered Droplet Data. For routine evaluation of droplet data, collecting particles on impinged slides by methods described above is satisfactory. Data recovered from settling chamber studies require the third power, or cube of the diameter, to be employed for particle assessment. This procedure is more involved mathematically. Additionally, there are a variety of statistical analyses that can be used to interpret the data.

e. Condensed Procedure for Impinged Slide Analysis.

(1) Measure 100-200 droplets on an exposed slide. Several horizontal sweeps or observation of isolated portions, selected at random, near the center of the slide will be satisfactory. Mark the counts in groups of five to simplify the procedure. A

laboratory type hand tally counter or similar device will aid in maintaining a running total of droplets.

Record the individual size totals and the grand total at the bottom of the (N) column.

(2) Using ten droplets counted as part of the sample, determine the spread factor by the method described on pages A-5/6. Droplets measured with a diameter of five or more divisions on the ocular scale will yield the most accurate results.

(3) Multiply the number of droplets in the (N) column by the eyepiece divisions for each size recorded. For example, 32 drops x 2 eyepiece divisions = 64 (Encl. 4). Record this number in the column marked "DN".

(4) Total the numbers in the (DN) column and record the number at the bottom of the page, for example 859 (Encl. 4).

(5) Divide each number in the % DN/EDN column by the (DN) total, and round

out the answers to the nearest whole number. For example 22 divided by 859 = 0.0256 = 0.03, or 3% (Encl. 4). Record this number in the (% DN/EDN) column.

(6) Accumulate the total by adding each number in the (% DN/EDN) column to

the (% ACCUM) number in the extreme right hand column. For example: 03+07 = 10; 10+11=21….The total of this column must equal 100 percent.

(7) Using semi-log graph paper, plot the accumulated percent for eyepiece division opposite the eyepiece number (vertical axis). Plot each number until 100% is reached.

(8) Using a straight edge, draw a line through the dots to give the "best fit."

(9) To determine the VMD, draw a vertical line from the 50% mark on the cumulative percent (horizontal) axis to the point where it intersects with the line drawn in (8) above. In this case, the intersection point is exactly at the five (5) eyepiece division mark.

(10) Multiply this number by the calibrated size of the eyepiece division in microns. For the microscope used in this example, each eyepiece division equals five (5) microns, therefore 5 x 5 = 25 microns.

(11) Using the computed spread factor, correct for droplet spread. In this example 25 (microns) x 0.5 (computed spread factor) = 12.5 microns VMD. Computation of the spread factor for this slide is not shown, but selected for simplified calculations.

(12) Percentage of droplets above or bellow a given size may be computed by referring to the chart. For example, if the percent less than 18 microns is to be determined, divide 18 by 5 (microns in each eyepiece division), and then divide it again by the spread factor. 18 divided by 5 = 3.6, divided by 0.5 = 7.2. Locate 7.2 on the eyepiece division axis using a straight edge, and move across until this line intersects with the line drawn in (8) above. Draw a vertical line down from this point to locate the percentage, in this case 82%.

f. Computer software. Several software programs are also currently available to calculate the droplet spectra analysis. Spreadsheet programs are also fairly easy to construct. For a free online software program see the website <http://www.adapcoinc.com>.

g. Hot Wire Calibration Method. The "Hot Wire" method, using equipment such as the KLD Labs DC-III Droplet Analyzer, provides a quick means of calibrating ULV sprayers. The "Hot Wire" method takes 15 minutes and provides an instantaneous readout on the spectrum of droplet sizes. The newer "Hot Wire" systems have electronic data collection systems, which can be downloaded onto a computer for record keeping and digital display of data. However, the "Hot Wire," actually a thin metal filament that can only be seen under high magnification, is a very delicate piece of equipment. Even with the greatest of care, the filaments can be easily broken. Most systems come with replacement or spare probes. Turnaround time required for factory repair of probes commonly is two weeks.

10. EQUIPMENT MAINTENANCE AND REPAIR

a. General Considerations. Equipment maintenance and repair are among the most frequently neglected factors in control programs. Many equipment operators understand little beyond the procedures necessary to start and stop the machine or adjust the flow rate as required, and they perform only the essential cleaning functions necessary to ready the machine for use in the next operation. Thus, most of the blame must rest with the operator himself if a machine fails and is unavailable when needed because some routine, but essential, repair or maintenance procedure was not accomplished. Administrative difficulties often occur, such as responsibility for operation being assigned to one department, and repair to another. Much of the equipment is completely foreign even to experienced maintenance or automotive mechanics; therefore, repair is delayed or performed poorly. When a self-reliant operator learns to maintain and repair his equipment properly, he may not have the opportunity to adequately train his replacement, and the process repeats itself. There is no certain solution to this problem, but conditions could be improved if command personnel were to insist upon training specially designated personnel in the procedures necessary to keep equipment operating with a minimum of "down time."

b. Equipment Maintenance Procedures. Because the design and configuration of ULV equipment varies so widely, specific information concerning each unit approved for military use is beyond the scope of this memorandum. The following are generalized procedures that are applicable to all ULV dispersal units:

(1) When a new machine is procured, duplicate copies of the operating and maintenance manuals, and keep one with the machine.

(2) Operators should be capable of performing maintenance on all portions of the machine except the engine and compressor systems.

(3) Equipment cleanliness, both internally and externally, is the most vital consideration. Pesticides and their solvents can cause irreversible damage to critical parts, especially equipment seals, gaskets and electrical wiring. Isopropyl alcohol or other acceptable solvents should be used to clean insecticide lines each time the machine is secured from operations. If insecticide is spilled on external portions of the machine, cleaning should be accomplished immediately. Some solvents may be harmful to equipment components. Acetone, for example, may damage seals or gaskets used in solenoid valves.

(4) Use a strainer for pesticide filling operations. Foreign matter in pesticides will significantly increase maintenance problems.

(5) Engine and compressor maintenance schedules, whether from the manufacturer or military command, should be carefully followed to ensure long machine life and proper performance.

(6) Spare parts for equipment should be procured when the machine is new to ensure their availability. For contingency operations, spares of the components most subject to failure may be desirable where resupply is difficult.

(7) The electronic controls and circuitry for ULV are not complex, and it should not be difficult for a capable technician to determine malfunctions. However, to simplify field repairs, replace the complete circuit board.

c. Routine Maintenance Items.

(1) Alemite grease gun with lubricating grease.

(2) Compressor oil (SAE 20 or 30).

d. Essential Operating Spare Parts.

(1) Solenoid valve assemblies and repair kits.

(2) Insecticide line tubing, ferrules and sleeves.

(3) Seals and gaskets.

(4) Flow meters and flow meter repair kits.

(5) Constant delivery pumps and repair kits.

(6) Insecticide and fuel strainer.

(7) Replaceable nozzle assembly components.

(8) Replaceable engine ignition parts.

(9) Air filters for carburetors and compressors.

(10) Replaceable electronic circuit boards and components.

e. Preparation for Storage of Engine/Blower Units. Before storing the aerosol generator the following preparations should be made:

(1) Prepare the insecticide metering system for storage according to instructions in its manual.

(2) Remove the cover and screen on the air intake silencer. Start the engine and pour one pint of lubricating oil (SAE 40) into the blower intake. Shut the engine down immediately. Replace the cover and screen. The oil will coat the entire inner surface of the blower. This will prevent a coat of rust from forming in the blower and will save the cost of a new blower or an expensive repair bill.

(3) Drain the engine carburetor.

(4) Store the aerosol generator under suitable cover so it is protected from the elements.

Appendix A

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
Bureau of Entomology and Plant Quarantine

May 1949 ET-267

Directions for Determining Particle Size of Aerosols and Fine Sprays

By A.H. Yeomans, Division of Control Investigations

The best method that has been found for determining the particle size of insecticidal aerosols and fine sprays is to deposit a sample on a glass slide and measure the particles under a high-power microscope. This method shows the complete range of particle sizes involved. Goodhue et. at. (3, 4) used it for measuring particle sizes of aerosols deposited by settling. This paper describes in detail the technique as it is now used.

Other, less satisfactory methods have been devised. Gibbs (1) used the rate of fall of the particles, and constructed a special instrument for timing their fall. Goodhue et al. (2) used a dye in the solution and by employing a photoelectric photometer determined the amount of deposit per unit of time. Other workers determined by chemical analysis the relative deposition on wires of different sizes, but their results did not clearly show the range in sizes. Instruments that pass a light beam through an aerosol cloud and measure the polarization of light scattering at right angles, or the number of spectre formed in the scattered light, are suitable only for measuring particles smaller than 2 microns in diameter.

Preparation of Slides

Particles of relatively nonvolatile materials can be measured before they evaporate. To prevent excessive spreading, filming, or coalescence, the slide must be coated with an oleophobic substance that will cause the individual droplets to maintain their convexity to some degree. Two of the most satisfactory materials for this purpose proved to be a 1-percent alcoholic solution of mannitan monolaurate, and a silicon product marketed under the trade name Dri-film 9987. The slides are first immersed in a cleaning solution, dried, then immersed in the oleophobic coating solution, and redried. When dry the slides should be lightly polished with a soft cloth. They may be stored in ordinary slide boxes for several days before they are used.

Particles of volatile materials, which evaporate rapidly, cannot be measured directly, but their size can be estimated by measuring the craters they leave at the points of contact on slides coated with magnesium oxide or carbon soot. It is important to apply the right thickness of coating for the range of particle sizes' anticipated. The relation between the actual particle diameter and the control circular spot (contrum) of the crater is illustrated in the excerpt from the report of the University of Chicago Toxicity Laboratory, which is appended. A dye coating of polyvinyl acetate suggested by workers in England for the same purpose proved less satisfactory than magnesium oxide or carbon soot.

Deposition of Particles on Slides

A sample of an aerosol or spray cloud can be deposited on a slide by impingement or by settling.

Deposition by impingement may be accomplished by moving the slide through an aerosol or spray cloud, or by moving the aerosol or spray cloud past a slide in fixed position. The velocity of movement in either case must be adjusted to the particle size range expected. The velocity must be increased as the average particle size decreases. Since the deposition is in proportion to the particle size, compensation must be made for this factor. The Cascade and Micro Impacters developed in England, wherein an aerosol cloud is drawn through a series of orifices to vary the velocity, and impinged on a different slide at each orifice, is useful only with very small particles, mostly out of the range of insecticidal aerosols and sprays.

Deposition by settling should be limited to particle size ranges below 20 microns in diameter. It may be accomplished by two means. An aerosol of spray cloud is released in an enclosure and allowed to settle onto slides placed on the floor or bottom. The cloud must be mixed to be uniform, and the aerosol or spray released in such a way as to prevent impingement on the sides or ceiling of the enclosure. The amount released should be small enough to prevent coalescing in the air or too heavy a deposit on the slide. Adequate time must be allowed for all the smaller particles to settle a distance equal to the height of the enclosure. Convection currents should be prevented as much as possible. A second and more rapid method is to draw the aerosol or spray cloud through an electrical precipitator in which slides have been placed. When the machine is turned on, all particles in the field are precipitated in a matter of seconds. Deposition by settling results in a slide representative of the entire range of particle sizes in the sample, with each size present in true proportion so that no adjustment or weighting is necessary.

Determination of Particle Size

After the sample of aerosol or spray has been deposited on a slide, it is placed under a microscope and the individual particles are measured with an eyepiece micrometer. A mechanical stage on the microscope is necessary, The diameter as measured on the slide is then corrected for the amount of spread that has taken place, and the diameter of the original sphere is determined.

At least 200 particles should be measured, according to DalaValle (5). The more homogeneous the aerosol or spray, the fewer particles need be counted. All particles should be counted as they are seen in the field. An accurate method is to measure all particles from one edge of a slide to the other and that pass through the micrometer scale as the slide is moved by the mechanical stage. Under some conditions of impingement, particles of the smaller size groups are congregated along the margin of the slide. Measurements in such areas should be avoided.

It is sometimes useful to photograph the particles or to project them on a screen through a microscope. Better results have been obtained, however, by measuring the particles directly as seen in the microscope. It is often more convenient to measure in terms of the divisions of an eyepiece micrometer, and convert these divisions into microns after the median has been determined.

Impinged Slides. Samples may be collected by impingement on a coated slide by waving the slide through an aerosol or spray cloud, or by drawing the aerosol or spray past a slide in fixed position, such as in a wind tunnel. The slide should be nearly perpendicular to the movement of the aerosol or spray. In either case the rate of deposition has been demonstrated to be in ratio to the square of the diameter. This rate of deposition was suggested by the Central Aerosol Laboratory of Columbia University and was based on Sell's law. To compensate for the decrease in the rate of deposition as the particle decreases in size, each diameter is multiplied by the number of particles of that size, f and expressed as the percent of the total of such products. Representative data illustrating this method are given in Table 1.

Table 1. Representative count of aerosol particles impinged on microscope slides.

Diameter (scale Divisions)	Number of Particles	Diameter Times Number of Particles	Percent of Total of Column 3	Accumulative Percentage
0.5	2	1	0.2	0.2
1.0	26	26	6.3	6.5
1.5	33	49.5	11.9	18.4
2.0	82	164	39.5	57.9
2.5	34	85	20.5	78.4
3.0	17	51	12.3	90.7
3.5	4	14	3.4	94.1
4.0	5	20	4.8	98.9
4.5	1	4.5	1.1	99.9
Total	204	415.0		

- The diameter is used in the first power only, since the particles impinge in the ratio to D^2, but the mass diameter is computed on the basis of their volume, which is a ratio to D^3. Therefore, the number of particles is multiplied by D^3/D^2, or by D.

The accumulative percentages from the last column are plotted on the arithmetic probability scales in Figure 1. The 50-percent point of the line so plotted is taken as the median of the particles as they appear on the slide. In this example the 50-percent point has a value of 2 scale divisions, or 30 microns, as each division we predetermined to equal 15 microns.

A correction factor must be determined for each slide. The original spherical droplet as it is impinged on the slide becomes a convex lens, and the extent of its spread from its original shape can be calculated by determining the focal length of the lens so formed. This method is described in Porton Report 2463 (6), a digest of which is appended. In the example cited the correction factor is 0.40; therefore 30 microns x 0.40 gives a median particle diameter of 12.0 microns.

Settled Slides. The median diameter of all the particles collected on a slide by gravitational settling or by electric precipitation is determined by calculating the volume of each particle. The diameter of the particles is measured in microns. The volume is determined by multiplying the cube of the corrected

diameter by π /6, or 0.5236. The volume of the particles of each diameter is expressed as a percentage of the total volume. Representative data illustrating this method are given in Table 2. The accumulative percentages from Table 2 are also plotted on the arithmetic probability scale in Figure 1 and the median particle diameter is determined to be 4.05 microns.

Table 2. A representative count of aerosol particles settled on a microscope slide. (Volume = 1/6 π D^3 = $0.5236D^3$)

Diameter (microns)	Number of Particles	Volume ($micron^3$)	Percent of Total Volume	Accumulative Percentage
1.4	1	1	0.01	0.01
2.1	55	267	3.3	3.31
2.8	101	1161	14.5	17.81
3.5	50	1119	14.0	31.81
4.2	57	2211	27.7	59.51
4.9	11	677	8.5	68.01
5.6	20	1838	23.0	91.01
6.3	4	524	60.6	97.61
7.0	1	180	2.3	99.91
Totals	300	7978 $microns^3$		

Figure 1. Percentage or total volume of aerosol samples below each stated particle diameter impinged and settled on microscope slides. The mass median diameter is determined from the 50-percent point. The correction factor for spread has been applied to the data for the settled slide (from Table 2) but not the data for the impinged slide (Table 1).

Spread-Factor Ratios

f' 2A	Correction Factor	f' 2A	Correction Factor	f' 2A	Correction Factor
1.48	0.60	2.0	0.48	4.0	0.375
1.50	0.58	2.1	0.47	4.8	0.35
1.55	0.55	2.2	0.46	5.0	0.34
1.60	0.54	2.3	0.45	5.5	0.33
1.65	0.53	2.6	0.44	6.0	0.32
1.70	0.52	2.65	0.43	6.8	0.31
1.75	0.51	2.8	0.42	7.0	0.30
1.80	0.50	3.1	0.41	8.0	0.29
1.95	0.49	3.3	0.40	9.0	0.28
				10.0	0.27

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(A digest of Porton Report No. 2463)

1. Use a compound high-power microscope.
2. Use a flat mirror.
3. Remove condenser.
4. Use outside light.

5. Focus on particle, and measure and record exact diameter.
6. Set reading on fine focus adjustment at zero.

7. Manipulate coarse focus adjustment and mirror until some distant object (window frame) is in as sharp a focus as possible, using the drop as a lens.
8. Then focus downward with fine focus adjustment until the drop is in clear focus.

9. The difference between the No. 6 reading of the fine focus adjustment (zero) and the no. 8 reading is the focal-length change.

10. Compute f' (focal-length change) and 2A (diameter of particle)

Example: The diameter of a particle covering 4 divisions in an eyepiece micrometer (1 division = 15.4 microns) would be 4 x 15.4 microns, or 61.6 microns. With a focal-length change of 206 microns, the spread factor of the particle would be 206/61.6, or 3.3.

With this factor of 3.3, the correction factor (f'/2A) for this drop would be 0.40 (see below for spread-factor ratios).

Appendix B

MICROSCOPE EYEPIECE MICROMETER CALIBRATION

1. Measurement of objects with the microscope requires calibration of the instrument. Two scales are required: an ocular or eyepiece micrometer (a glass disc bearing a scale of 50 or 100 divisions numbered at intervals to facilitate reading), and a stage micrometer (a glass slide with a scale divided into units of 0.1 mm and 0.01 mm).

2. Remove eyepiece, unscrew the top lens, and note the circular shelf inside. Clean the eyepiece micrometer disc with lens paper and place it carefully in the eyepiece so that it rests on the shelf. Replace the top lens and insert the eyepiece in the microscope. With moderate illumination, the scale should be in sharp focus. If its numbers are backwards, the disc is upside down and must be turned over. This scale, regardless of the objective used, will appear the same size when viewed within the eyepiece, and must be calibrated for each lens combination (i.e. eyepiece and objective) provided by the microscope. The stage micrometer is used for that purpose. With the lowest power objective in position, place the stage micrometer on the stage and focus on its scale. The ruling may be in 0.01 mm units throughout its length or only at one end, with the remainder divided into 0.1 mm units. Rotate the eyepiece until its scale is either superimposed on, or very close and parallel to, the stage scale. Move the stage micrometer so that its zero line is exactly even with, or superimposed on, that of the eyepiece scale. Then, as far as possible from that point, find another at which the two scales coincide. Count the spaces on each scale between these points and determine the actual distance on the stage micrometer. That distance divided by the number of eyepiece spaces gives the actual length measured by one space

on the eyepiece scale. Following is an actual calibration using a 10x eyepiece and a 16 mm (10x) objective:

100 eyepiece spaces = 65 stage spaces, each 0.01 mm long

100 eyepiece spaces = 0.65 mm

1 eyepiece space = 0.0065 mm or 6.5 microns

In the same manner, calibrate all other objectives of the microscope and record the values obtained. Because scale lines on the stage micrometer have appreciable thickness at high magnification, readings are more accurate if taken at their edges in finding points at which the two scales coincide. The calibration value is inversely proportional to the magnification. Thus, the distance measured by one eyepiece space with a 43x (4mm) objective is 10/43 that when the 10x (16 mm) objective is used. Actually, lenses vary slightly from their stated magnifications, making it necessary to calibrate each lens combination. Also, calibrations are accurate for a given instrument only if the length of the body tube remains unchanged.

Appendix C

REMOVABLE SHEETS

FOR

ROUTINE DROPLET COLLECTION

AND

CALIBRATION PROCEDURES

Appendix C (Enclosure 1)

INSTRUCTIONS FOR DETERMINING FLOW RATE

A. GENERAL

1. Two people are needed to perform the calibration.

2. A minimum of two gallons of insecticide in the tank is necessary.

3. Two containers are needed. The large container can be a used plastic bleach or milk bottle with a portion of the top section cut away but leaving the handle. The small container must be a plastic wide mouth conical pharmaceutical graduate. This container must be capable of measuring a minimum of eight fluid ounces or 250 milliliters.

B. INSTRUCTIONS

1. Start the engine. Set the operating air pressure after the machine has warmed up, usually five psi.

2. Turn on the solenoid valve by activating the toggle switch.

3. Open the flow meter valve. Let the ball go to the highest setting, and be sure that there are no bubbles in the lines. Be sure all insecticide lines are filled.

4. Cut off the solenoid valve.

5. Use protective gloves for all subsequent steps. Disconnect the insecticide discharge tube from the fog head. Hold both containers in one hand at the same level as the discharge tube connection, and place the discharge tube over the large container. The discharge line must be held steady during flow rate measurement.

6. Turn on the solenoid valve, and set the flow meter to the point indicated by the flow meter chart for the specific insecticide you are using. Measure from the center of the ball. Allow insecticide to flow into the large container to ensure steady flow and stabilization of temperature. This is approximately a setting of nine for Fayfanon™ .

7. Record flow meter setting, air pressure, liquid and air temperatures.

8. The person operating the controls will time the flow rate by signaling the person holding the discharge tube to shift it from the large container to the graduate. Timing of flow starts at this instant. Time the flow for 30 seconds. At the end of 30 seconds, signal transfer of the insecticide line back to the large container. Cut off the solenoid valve.

9. Observe the measured flow, and multiply the result by 2 to get the flow rate per minute. Increase or decrease the flow meter setting to obtain the correct flow rate by repeating steps 6, 7 and 8 above.

10. Reconnect the insecticide line to the fog head. While the machine is still running, turn on the solenoid valve. The flow meter ball setting will rise due to the added venturi action of the nozzle. Readjust the flow meter valve to the setting determined for proper flow rate.

11. Flow rate variations occur from machine to machine. Therefore, a calibration

chart based on liquid temperature must be made for your particular machine. Record flow meter settings for each five degrees of temperature between 60 and 100 degrees while maintaining the proper insecticide flowrate. These temperatures can be obtained starting early in the morning and progressing through the day.

12. CLEANING INSTRUCTIONS:

a. Remove the filler cap to prevent pressure buildup on the insecticide tank.

b. Remove the insecticide discharge line at the tank. Place this line in a container with approximately one pint of isopropyl alcohol. DO NOT USE ACETONE

FOR CLEANING THE MACHINE.

c. Remove the air pressure line on the insecticide tank to prevent accidental discharge of contents.

d. Start the machine. Turn on the solenoid valve and adjust the flow meter to the highest setting. Run the machine until all the alcohol is exhausted.

Appendix C (Enclosure 2)

PROCEDURE FOR COLLECTING DROPLETS FROM ULV MACHINES FOR MICROSCOPIC ANALYSIS

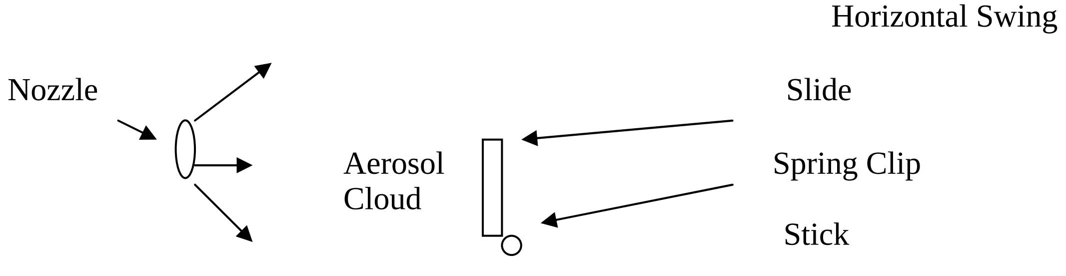
1. A set of Teflon® -coated, numbered slides, cover slides, and spacers have been provided to you for droplet collection. Careful attention to the instructions will enable us to more effectively evaluate your equipment.

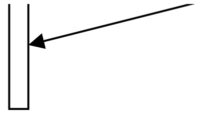
2. Proceed as follows:

a. Set the machine to the proper flow rate according to the instructions that come with the machine.

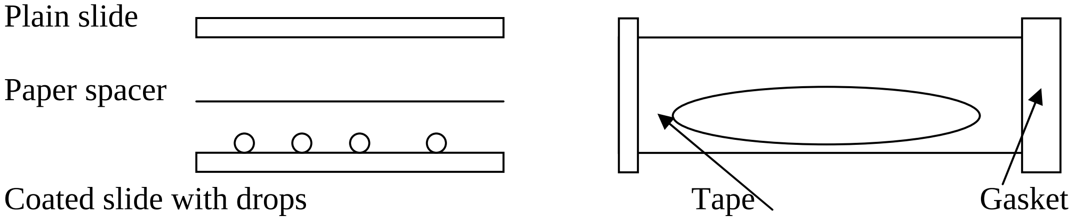
b. Move the fogging head to a horizontal position so the insecticide flow is parallel to the ground. This position is for testing only; move back to the original position for operating purposes (45^{o}).

c. With the machine operating properly, take three slide samples at eight (8) feet. The wind speed should not exceed ten mph for the test. The slide is attached to a six foot stick (broom handle satisfactory) with a large spring clip at the end. Tape the clip to the stick firmly. Wave the slide through the insecticide cloud vertically to the flow. The exposure time for the swing should be approximately one (1) second. The droplets must be collected on the numbered side of the slide, so face it towards the cloud.





d. After the sample is obtained, put one of the spacing papers provided on the slide (slide number side up), and cover the paper and the exposed slide with a plain microscope slide, making a "sandwich" of the two slides and the paper.



e. Use cellophane tape at both ends of the slide and wrap it securely.

f. Wrap the slides in tissue paper to prevent breaking and return them in the mailing box provided.

g. If there are any questions, contact DVECC, AUTOVON 942-2424/5,

COM 904-542-2424/5, fax 904-542-4324, email dvj0jrb@jax10.med.navy.mil

3. Record the operating and weather information on the data sheet provided in Enclosure 3, Appendix C (page C-3).

Submit slides to:

a. Navy:

Officer in Charge, Disease Vector Ecology and Control Center, ATTN: Testing and Evaluation, Box 43, Naval Air Station, Jacksonville, FL 32212

b. Army:

1. Commander, USACHPPM-North, Entomological Sciences Division, ATTN: MCHB-AN-ES, Bldg 4411, Ft George G. Meade, MD 20755-5225
2. Commander, USACHPPM-South, Entomological Sciences Division, ATTN: MCHB-AS-ES, 1312 Cobb St., Ft McPherson, GA 30330-1075
3. Commander, USACHPPM-West, Entomological Sciences Division, ATTN: MCHB-AS-ES, Box 339500-MS 115, Ft Lewis, WA 98433-9500

Appendix C (Enclosure 3)

ULV INFORMATION SHEET

Note: Be sure to calibrate the machine before collecting droplet samples.

Please record the following information:

1. Date slides taken____

2. Machine type, manufacturer, serial number____________________________

3. Machine flow rate in ounces or milliliters per minute____________________

4. Machine air pressure ____

5. Machine liquid temperature____________________________________

6. Outside air temperature______________________________________

7. Flow meter setting____

8. Insecticide used____

9. Wind speed (MPH)____

Appendix C (Enclosure 4)

ULV DROPLET TEST (SAMPLE)

EYEPIECE DIVISIONS	TALLY	N	DN	%(DN/EDN)	% ACCUM
1	///// ///// ///// ///// //	22	22	03	03
2	///// ///// ///// ///// ///// ///// //	32	64	07	10
3	///// ///// ///// ///// ///// ///// /	31	93	11	21
4	///// ///// ///// ///// ///// ///	28	112	13	34
5	///// ///// ///// ///// ///// ////	29	145	17	51

6	///// ///// ///// ///// /	21	126	15	66
7	///// ///// /////	15	105	12	78
8	///// /////	10	80	09	87
9	///// ///	8	72	08	95
10	////	4	40	05	100
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
TOTALS		**200**	**859**		

AVERAGE DROPLET DIAMETER = ___________________MICRONS

(TOTAL D x N / TOTAL NO. DROPLETS) ENCLOSURE (4)

VMD calculation 5 X 5 X 0.5 = 12.5 microns

ULV DROPLET TEST (Worksheet)

EYEPIECE DIVISIONS	TALLY	N	DN	%(DN/EDN)	% ACCUM
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
TOTALS					

AVERAGE DROPLET DIAMETER = __________________MICRONS

(TOTAL D x N / TOTAL NO. DROPLETS)

(Enclosure 5 (semilogarthmic graph paper) is not provided in the electronic version of TIM 13.)

APPENDIX D

ULV DROPLET ANALYSIS TEST KIT COMPONENTS

Components include:

1. Four foot long ¾ inch diameter or 1 inch diameter wooden dowel
2. One each ¼ inch diameter X 1 ½ inch long bolt (can use 10/32 inch up to ¼ inch diameter bolt)
3. Two flat washers, ¼ inch (or size to match other diameter bolts, if used).
4. One wing nut, ¼ inch

   Note. Use the above materiel to construct a wooden dowel stick with slotted end, bolt, washers, and wing nut to clamp slides into the slotted stick. The stick can be made using a 3/4 or 1inch diameter dowel, approximately 4 feet long. Cut a slit, using a saw, approximately 4 inches long in one end of the dowel so that it can hold a Teflon®-coated slide. Next drill a hole, using a drill bit which matches the diameter of the 1 ½ inch bolt, through the dowel approximately 3 inches down from the dowel end with the slit. Microscope slides placed one inch into the slit can then be tightened into the slit using a

¼ inch x 1 ½ inch bolt inserted into the drilled hole and fastened with washers and wing nut. Wood dowel, bolts, flat washers, and wing nuts can be purchased at a local hardware store.

5. Graduated Cylinder, polypropylene economy graduated, size 250 ml. The graduated cylinder is used for measuring flow rates. A source is:

   Fisher Scientific
   Phone: 1-800-926-1166
   NalgeneJ, polypropylene economy graduated cylinder
   Catalogue No. 08-572-6E
   Unit Price - $6.20 each

6. Teflon®-coated slides:

   BioQuip Products
   17803 LaSalle Avenue
   Gardenia, CA 90248-3602
   Phone: (310) 324-0620; Fax: (310) 324-7931
   Cost: $88.00 for a box of 25 or $19.00 for a box of 5.

   Or

   Summit Chemical Company
   7657 Canton Center Dr.
   Baltimore, MD 21224-2079
   Phone: 410.282.5200

7. Cover slides (NSN 6640-00-494-3808)
8. Mailer and/or shipper tubes:

   Fisher Scientific
   Phone: 1-800-926-1166
   Catalogue No. 03-526
   Cost $97.70 for 300 foam mailers

   Fisher Scientific
   Phone: 1-800-926-1166
   Catalogue No 03-526A
   Cost: $54.00 for 300 mailing sleeves

9. Paper gasket. Make paper gaskets, using manila folders or 3/5 cards. First cut the gasket materiel to the same dimensions as the slide (1"x3"). Then carefully cut out the center so that you have a "window frame" effect. The edges of the "window frame" should be about ¼ inches thick. This gasket is used as a spacer between Teflon®-coated slide and the 1"x 3" slide used as a cover. See para 2d, e, and f, Enclosure 2 to Appendix C, above.
10. Tape. Cellophane tape is commonly found in most convenience stores. Use

cellophane tape at both ends of the slide and wrap it securely.

11. Cleaning Brush, size 2-inch diameter x 6-inch long brush, with overall length of 20 inches. Brush is used to clean graduated cylinder after use.
    Fisher Scientific
    Nessler tube brush
    Catalogue No 03-621-B
    Cost: $9.76 each

Appendix E

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Mount, G. A., N.W. Pierce and K.F. Baldwin. 1975. Comparison of two aerosol generator nozzle Systems: estimates of droplet size and caged mosquito assays. Mosquito News 35(4): 501-503.

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Appendix F

SOURCES OF SUPPLY FOR ULV EQUIPMENT AND MATERIALS*

A. ULV Dispersal Equipment Manufacturers (see also TIM 19):

(1) Beecomist Systems Incorporated, 31 Meeting House Rd, Telford, PA 18969 (215) 542-8909, FAX: (215) 721-0751. AGULVE, PROMIST 15 and 25.

(2) Curtis-Dyna Products, P.O. Box 297, Westfield, IN 46074 (317) 896-2561. Truck and hand-held sprayers.

(3) London Fog Company, 505 Brimhall Ave., Long Lake, MN 55356 (612) 473-5366, FAX: (612) 473-5302. Truck and hand-held sprayers.

(4) Clarke Mosquito Products, 159 North Garden Ave., Roselle, IL 60172

(630) 894-2000, FAX: (800) 832-9344. Truck and hand-held sprayers.

(5) Whitmire Micro-Gen Research Laboratories, 3568 Tree Court Industrial Blvd., St. Louis, MO 63122 (800) 777-8570, FAX: (314) 225-3739.

(6) Dramm Corporation, 2000 S 18th St., Manitowoc, WI 54220-6325 (920) 684-0227. ULVA Fan.

B. Distributors of Equipment and Supplies:

(1) Teflon® Slide Supply Source

Summit Chemical Company
7657 Canton Center Dr.
Baltimore, MD 21224-2079
Phone: (410) 282-5200

BioQuip Products
7803 LaSalle Avenue
Gardenia, CA 90248-3602
Phone: (310) 324-0620
Fax: (310) 324-7931
Cost: $88.00 for a box of 25 or $19.00 for a box of 5.

(2) Eyepiece (Ocular) Micrometer, with etched scale of 100 numbered divisions that fits into the eyepiece's base. Note: Prior to purchase, ensure that the micrometer will fit into the model of the microscope that it will be used with. Cost is approximately $35.00.

(3) Stage Micrometer. Used to calibrate the ocular scale in the eyepieces. Glass slide, with a millimeter divided into 100 parts of 10 microns each. Approximate cost is $50.00 to $100.00. Note: Prior to purchase, ensure that the micrometer will fit the model of the microscope that it will be used with. Cost is approximately $35.00.

(4) See Appendix D, above, for materials needed to make a ULV droplet analysis test kit.

* Mention of a product or supply source does not constitute an endorsement of the products named or criticism of similar ones not mentioned. Mention of trade names does not constitute a guarantee or warranty of the products by the AFPMB, the Military Services, or the Department of Defense.